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Collisional Excitation of Electronic Levels in C II and C III*

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ABSTRACT

The $4d\ ^3D$ term in C III and the $2p^3\ ^2P^o$ term in C II were excited by sending energetic C^+ ions through a carbon foil. The transitions $3p\ ^3P^o - 4d\ ^3D$ (λ 1621) in C III and $2p^2\ ^2P - 2p^3\ ^2P^o$ (λ 1720) in C II were detected photoelectrically. A third line, λ 1555, was also seen; its source could be C I or C IV. We corroborate the earlier result that the excitation distribution differs markedly from the charge distribution in the beam.

INTRODUCTION

A number of experiments[1-12] have demonstrated that the passage of fast ions through a thin foil leads to the excitation of electronic levels in the particles comprising the beam. The decays of the levels

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can be detected spectroscopically. We report another such experiment. In the present case, the element carbon was studied.

A carbon beam (C^+, intensity $\sim 3\ \mu$amp, energy 4.5 MeV) was extracted from the Los Alamos vertical Van de Graaff accelerator and sent through a self-supporting carbon foil[13], the thickness of which was 5 - 10 μgm/cm^2. The transmitted beam was collected in a shielded Faraday cup which was connected to a current integrator. A modified Jarrell-Ash, 0.5 meter, Seya-Namioka, vacuum spectrometer, coupled directly to the target chamber in which the pressure was $\sim 2 \times 10^{-6}$ torr, viewed the particle beam at a nominal angle of 90°. The observed portion of the beam was immediately adjacent to the foil on the downstream side. The entrance slit on the spectrometer had a width of 100 microns.

After being diffracted by a _____ line/mm grating, the light passed through an exit slit, 100 microns wide, and was detected by an Ascop 541F photomultiplier which, with a Li F window, is sensitive to photons in the wavelength range between 1050 and 3500 A. The photomultiplier responded to individual photons, the pulses from which were amplified and counted with a scaler or plotted on an x-y recorder.

The wavelength scale was calibrated, to ± 3A, by means of a mercury discharge in a quartz envelope. For calibration purposes, the detector was a sodium salicylate coated EMI photomultiplier with a more extensive wavelength response than the Ascop photomultiplier. The calibration line of shortest wavelength was at 1849.5 A. The calibration curve was a straight line through 4358 A; by noting the position of the zero order reflection, the calibration curve extended was found to pass through zero.

DATA AND DISCUSSION

In Fig. 1, which shows one of the wavelength scans, three spectral lines are apparent. Two of them, with measured wavelengths of 1720 and 1620 A, are attributed to the transitions $2p^3\ {}^3P - 2p^3\ {}^3P^0$ in C II and $3p\ {}^3P^0 - 4d\ {}^3D$ in C III, respectively. The third, at 1555 A might come from C I ($2p^2\ {}^3P - 3s\ {}^3P^0$) or C IV ($2s\ {}^2S - 2p\ {}^2P^0$).

The first point to note is that the discussion by Zaidins[14] of the charge distributions resulting from sending 4.5 MeV C^+ ions through a thin foil gives the following: C^{5+}, 15%; C^{4+}, 60%; C^{3+}, 25%. Hence it was distinctly unexpected to find that the observed excitations occurred only for ionizations of 3+ or less. This kind of discrepancy has been noted previously[8,13,15], but seems more marked here than for the elements and energy ranges studied earlier. It should be realized that $C^{3,4,5+}$ all have excited levels which can decay with the emission of light in the wavelength range of the present experiment.

We now consider the observed transitions, first treating the case of C III.

<u>C III.</u>

There are $4s\ {}^1S$, $4s\ {}^3S$, and $4d\ {}^3P^0$ levels at energies slightly below that of the $4d\ {}^3D$ level which decay by transitions within the range of the experiment. However, those transitions were not detected. Since the strengths of the appropriate decays are 5 to 16 times smaller than the strength of λ 1621, this may well account for our failure to observe them.

C II

Although λ 1720 is definitely associated with the decay of the $2p^3\ ^2P^0$ level in C II, we did not see λ 1384 which derives from the same level and has virtually the same strength (0.94 vs. 1.27). Moreover λ 1760 ($2p^2\ ^2D$ - $3p\ ^2P^0$) was not detected although the $3p\ ^2P^0$ level is at an excitation of 131,730 cm^{-1} whereas the $2p^3\ ^2P^0$ level is at 168,750 cm^{-1}. If we use the model of Ref. 15, we may understand this difference as follows. Let the excitation be represented by:

$$1s^2 2s^2 (^1S) 2p\ ^2P^0 + e \rightarrow 1s^2 2p^3\ ^2P^0 + e'$$

$$\rightarrow 1s^2 2s^2 (^1S) 3p\ ^2P^0 + e'$$

The first of these clearly requires a greater transfer of angular momentum than the latter, and Ref. 15 notes that large transfers seem to be favored in the beam-foil collisions.

λ 1555

We cannot make an unambiguous assignment for this line. However, the beam-foil source has not excited neutral atoms[12,16], except for H and He, so it is not unlikely that the present line comes from C IV, $2s\ ^2S$ - $2p\ ^2P^0$.

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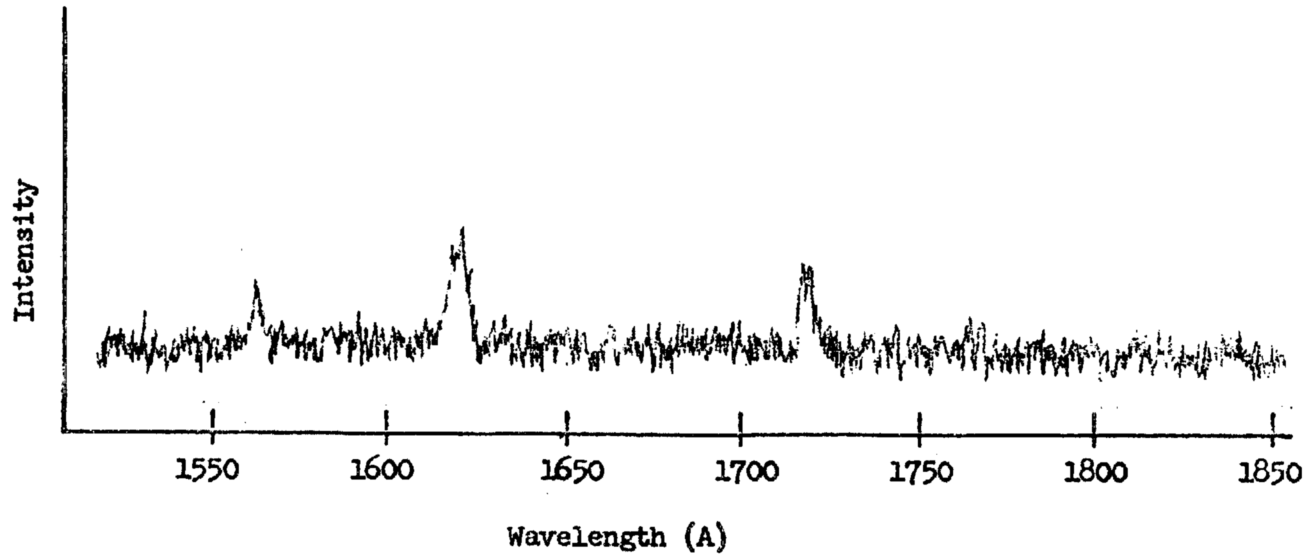

Fig. 1. Intensity Scan.

Profiles of Spectral Lines Observed In the Beam-Foil Method.* L. C. Marquet (introduced by William S. Bickel) and William S. Bickel, U. of Arizona.— When fast, foil-excited ions are used as a light source,[1] the resulting spectral lines are Doppler broadened because the radiating particles are moving and the spectrograph has a finite acceptance angle. An exact expression has been obtained for the line profile produced by a stigmatic spectrograph without vignetting. For $\beta^2 << 1$, the intensity is $I(\lambda) \sim \left[\frac{\theta^2}{4} - \left(\frac{\lambda_0 - \lambda}{\beta\ \lambda_0}\right)^2 \right]^{\frac{1}{2}}$ when the square root is real, and zero otherwise. Theta is the spectrograph's acceptance angle. The line width at half-maximum is $\Delta\lambda \sim 0.866\ \theta\ \beta\ \lambda_0$. Vignetting causes the line shape to deviate from the theoretical profile. For a Meinel-type spectrograph, the effect can give doubled line images. Proper vignetting avoids this doubling and gives spectral lines narrower than predicted by the general formula. Doppler broadening can also be overcome with a method, suggested by Meinel, which will be described.

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[1]Bashkin et al., J. Opt. Soc. Am. 56, 1064 (1966).

To precede: Double-Beam Experiments Using the Beam-Foil Method.*
William S. Bickel.

(13.2)

SUBMITTED FOR NEW YORK APS MEETING, JANUARY 30 - FEBRUARY 2, 1967.

Double-Beam Experiments Using the Beam-Foil Method.* William S. Bickel, U. of Arizona.—A beam of hydrogen molecular ions (HHH^+), accelerated to 300 keV with a Van de Graaff accelerator, was passed through two parallel slits, each 0.8 mm wide, creating two identical parallel beams separated by 0.8 mm. The beams were sent through one or more carbon foils and were studied via Balmer radiation which appeared on the downstream side of the foils. The light was either integrated, or resolved with a stigmatic grating spectrograph. One of the beams could be perturbed and simultaneous observations could be made on it and the unperturbed companion beam. It was found that the light intensity was greater, the greater the foil thickness, suggesting that the foils do not produce excitation equilibrium. The foil thickness increased with bombardment time. Applying a transverse electric field increased the light output. Sending a beam through two foils and a transverse electric field clearly showed the Stark effect described previously.[1]

*Supported in part by NASA Grant NsG-628.

[1]Bashkin, Bickel, Fink, and Wangsness, Phys. Rev. Letters 15, 284 (1965).

To precede: Excitation of Oxygen by the Beam-Foil Method,
K. S. Burton, S. Bashkin, and W. S. Bickel.

To follow: Profiles of Spectral Lines Observed in the Beam-Foil Method,
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Excitation of Oxygen by Beam-Foil Method.* K. S. Burton (introduced by S. Bashkin), S. Bashkin, and W. S. Bickel, U. of Arizona.—Singly charged monatomic and diatomic oxygen ions, accelerated to energies between 250 keV and 2 MeV, were multiply ionized and excited to various electronic states on passing through a thin carbon foil. Only monatomic ions emerged from the foil. The radiative decay of the excited ions was detected with a (Meinel) grating spectrograph (f/0.8) having a dispersion of 35 A/mm in second order. Data were recorded on Eastman 103a-o plates for wavelengths between 2800 and 4700 A. The present experiments have significantly better resolution, and extend to shorter wavelengths, than earlier work along these lines.[1] Approximately 140 spectral lines were seen and have been identified as belonging to some 50 multiplets in O II through O VI. In agreement with earlier findings on neon[2], it appears that levels of high multiplicity and high orbital angular momentum are preferentially populated. The dependence of line intensity on the energy of the incident particle will be discussed.

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[1]Bashkin et al., J. Opt. Soc. Am. 56, 1064 (1966).

[2]Bashkin, Heroux, and Wangsness, Phys. Rev. (to be published).

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